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This article reviews the fluid-electrolyte balance which is altered by exercise in hot environments at a variety of durations--focusing on sodium chloride losses. Recommendations are presented to assist athletes in maintaining electrolyte balance practically. Because of the journal involved, athletic situations and circumstances are highlighted.

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TITLE: IS SALT AT FAULT?

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IS SALT AT FAULT?

Nearly all runners recognize that dehydration (via sweating) causes body fluids to become too concentrated, and that they must replace water lost during hot weather running. Few runners recognize, however, that heat illness may be experienced when body fluids become too dilute. Hyponatremia (the medical term for a low sodium level in the blood) is caused by large losses of salt in sweat and the consumption of large quantities of pure water. Both of these factors cause body fluids to become too dilute.

Three recent medical publications have described marathoners and ultramarathoners who experienced severe hyponatremia. Their symptoms included mental confusion, seizures, coma, and excessive fluid in the lungs and brain. Also, 19 competitors (out of 64 examined) in Hawaii's Ironman Triathlon had abnormally low blood salt (sodium and chloride) levels at the finish line.

The Western States 100 Mile Run also should provide a perfect setting for the symptoms of hyponatremia to develop. The third leg, from mile 62 to mile 80, involves a chain of rugged California canyons, temperatures of 94°F or higher, stifling humidity, and dormant air. Yet, one of the authors (R.L.) measured the blood sodium concentrations of nearly 70 Western States 100 competitors and found them all to be within

the normal range. This suggests that salt losses were offset by the food (including pastry, peanut butter and jelly sandwiches, salami sandwiches, or high-energy bars) and fluids (water and sport drinks) consumed by these well-informed runners.

TOO LITTLE OR TOO MUCH?

From the 1950's through the 1970's, American athletes overused salt tablets. This resulted from laboratory studies conducted after World War II. Because U.S. soldiers in hot, humid environments experienced hyponatremia, large salt supplements (2 - 6 tsp) were recommended for men working 8 - 12 hour shifts. This advice was erroneously applied to athletes exposed to heat for only 1 - 2 hours per day.

Today, the average American consumes the equivalent of 1 - 1.5 teaspoons (8 - 12 grams) of table salt (sodium chloride) in his/her daily diet. This means that American short- or medium-distance runners need little or no extra salt in their diets, in most situations. Studies have shown that heat acclimatized humans need much less than 1 - 1.5 teaspoons of sodium chloride to survive in hot environments. This is because the hormone aldosterone acts to reduce salt losses in sweat and urine. However, during the initial 3 - 5 days of heat acclimatization, when the body has not fully adapted to exercise in the heat, salt requirements are higher. This is true because the kidney requires 3 - 5 days (and sweat glands

require 5 - 10 days) to adapt to ~~their~~ full salt-conserving capacity.

It also should be recognized that there are three negative consequences of eating too much salt. (1) Some forms of heat illness may be aggravated by excessive salt intake. (2) Heat acclimatization may be impaired in humans who load their diets with excessive salt supplements (i.e. 2.9 - 3.8 tsp per day). (3) If body fluids become concentrated during exercise, it is not wise to load the body with salt, and further increase the concentration.

A THOUGHTFUL APPROACH

By now, it should be evident that salt requirements are unique to each runner, and to each event. For example, Table 1 illustrates potential salt losses during a 10 kilometer run, a marathon, and an ultramarathon. Considering the fact that the average U.S. citizen consumes 1 - 1.5 teaspoons of sodium chloride per day, it is logical that the salt losses incurred during a 10 kilometer race (0 - 0.75 tsp) can be replaced easily by normal dietary intake.

{Table 1

However, runners may require salt supplements in marathon or ultramarathon races. Up to 3.7 teaspoons of sodium chloride may be lost by unacclimatized runners during a hot weather marathon, while 6.8 -11.6 teaspoons may be lost during a 100 mile run. The latter distance clearly requires that competitors plan salt and fluid intake carefully.

Back-of-the-pack marathon runners have a greater risk of hyponatremia because they (1) may lose more than 6 quarts of sweat, (2) usually lose more salt per quart of sweat than elite runners, and (3) tend to drink more fluid at each aid station than faster runners. If these runners drink only pure water and eat no salt-containing foods, they increase their risk of hyponatremia by combining a large salt loss with a large pure water gain. This suggests that dilute fluids containing salt may be beneficial in some situations.

REPLACING LOST SALT

The following 12 guidelines will help you to intelligently replace salt losses, during or after hot weather training and competition.

1. Because most runners train through an entire summer without heat illness, it is logical that salt supplements generally are not needed in this country. Extra salt may be needed if body weight decreases by 3% (a 4.5 lb loss for a 150 lb runner) or more on successive days, or if daily training lasts longer than two hours. In these situations, it is also wise to consume fruits which contain potassium (i.e. bananas, watermellon).
2. During the initial 3 - 5 days of heat acclimatization, liberal salting of food is recommended if large quantities of sweat are lost. Thereafter, the need for extra salt decreases and a normal American diet should meet salt requirements. If you eat slightly more salt than you actually require, little

harm will be done because it will pass out of your body in urine.

3. Weighing yourself each morning will give you a trend of your weight gain or loss, but the amount of perspiration lost can best be estimated by weighing in the nude, before and after a run. (Remember: "a pint weighs a pound the world around".) If your fluid intake equalled your sweat loss, you drank two 8 ounce cups (1 pint) of fluid for each pound of body weight lost.

4. Prior to a race or training run, estimate the salt you expect to lose (see sample calculations in the sidebar on page --) and compare it to the average daily intake for U.S. citizens (1 - 1.5 tsp). If you are unacclimatized and expect to lose much more salt than you will consume, it is wise to add extra salt to your food that day.

{ Sideba

5. Salt losses may be replaced during or after exercise. Table 2 lists the sodium chloride content of several beverages and food items. Following exercise, salt losses can be replaced conveniently by eating soup or broth.

{ Table 2

6. Your body will store fluids in proportion to the amount of salt you eat. For each level teaspoon of supplemental salt added to your diet (e.g. salty popcorn or ham), you require an additional 1.5 quarts (3 pounds) of fluid in your diet.

7. Following a marathon or ultramarathon, two factors indicate an increased risk of hyponatremia: (a) body weight gain during the race, and (b) consumption of large quantities of pure

water.

8. Salt tablets are not recommended because approximately 10 - 20% of all runners experience stomach upset after consuming them. If salt tablets must be used, they should be crushed and dissolved in water, prior to use.

9. The most likely cause of heat cramps is a whole-body deficit of sodium chloride. Drinking mildly salted fluids (0.1 tsp of table salt per quart) and rest will bring relief. The most popular sport drinks contain approximately 0.1 to 0.2 teaspoons of sodium chloride per quart (see Table 2).

10. The American Medical Joggers Association recommends that you drink both pure water and beverages which contain some salt. Extremely concentrated beverages (which contain a lot of sugar or salt) delay stomach emptying during exercise, and should be avoided.

11. To determine your daily salt intake accurately, you may purchase a nutrition guidebook which lists the exact salt content of common foods.

12. If you eat a very low salt diet, you may be predisposed to heat illness. If you eat a very high salt diet, you may be predisposed to high blood pressure. In either case, you should consult a sports-oriented physician when planning to exercise in the heat.

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Table 1 - Fluid and salt turnover during hot weather running.

MEASUREMENT (UNIT)	EVENT		
	6.21 mi (10k)	26.2 mi (42.1k)	100 mi (161k) *
Duration of run (hr)	0.5 - 1	2 - 4.4	20 - 29.5
Running pace (min/mi)	5:00-10:00	5:00-10:00	12:00-18:00
Total water intake (qt)	0 - 0.5	0.5 - 2	17 - 38
Sweat rate (qt/hr)	1 - 1.5	1 - 1.5	0.7 - 1.2
Total sweat lost (qt)	0.5 - 1.5	2 - 6.6	18 - 35
Salt lost in sweat (tsp) **	0.1 - 0.8	0.3 - 3.3	5.1 - 10.1
Total salt lost in sweat and urine (tsp) ***	0.1 - 0.8	0.3 - 3.7	6.8 - 11.6

* - Calculated from observations made by Dr. Lind at 1987 Western States 100 Mile Run.

** - Heredity, diet, training status and heat acclimatization status alter these values. Salt loss per quart equals 0.1-0.5 teaspoons.

*** - Based on urine contents of 1.25 teaspoons of sodium chloride per quart.

Table 2 - Salt (sodium chloride) in various foods and beverages.

FLUID	SALT CONTENT GRAMS	LEVEL TEASPOONS
Soup, stew *	7.8-9.8	1-1.2
Tomato juice, bottled	6.1	1.1
Sport drink A	1.2	0.2
1% lowfat milk	1.2	0.2
Sport drink B	0.6	0.1
Brewed tea	0.2	**
Apple juice	0.2	**
Cranberry juice cocktail	0.1	**
Cola and Uncola	0.1	**
Brewed coffee	**	**
Orange juice, fresh	**	**
Grapefruit juice, fresh	**	**
Beer	**	**

* - Examples: canned chicken noodle, beef bouillon, beef stew or vegetable beef

** - less than 0.1

SIDE BAR -

TITLE: Estimating Salt Losses During Exercise

1. Measure your sweat rate (qt/hr) by weighing yourself nude on an accurate scale, before and after running 1 hour (approximating race pace). The difference (D) in body weight equals the amount of water you lost in sweat during your run. The weather conditions should be similar to those which you anticipate for race day. Typically, sweat rate will be 1 - 1.5 qt per hour. (Remember that 1 pt weighs 1 lb and 1 qt weighs 2 lb.)

2. If you drink fluids during this 1 hour run, be sure to weigh them and subtract this from D (item 1 above).

3. One quart of sweat contains an average of 1/4 level teaspoon of sodium chloride. If you multiply this number by D (see items 1 and 2 above), it will approximate your salt loss per hour of running.

4. To calculate your salt loss during an entire race, multiply your answer in step 3 by the number of hours of total running.

SAMPLE CALCULATION:

Step		
1	Body weight before 1 hour run	150 lb
	Body weight after 1 hour run	− 146 lb
	Body weight difference	4 lb
2	Water consumed during run (1 pt) *	− 1 lb
	Total sweat loss *	3 lb = 1.5 qt
3	Sweat salt content	X .25 tsp/qt
	Salt loss per hour	0.375 tsp/hr
4	Hours of total running	X 4 hr
	Total salt loss during 4 hour event	1.5 tsp **

* - 1 pint weighs 1 lb, 1 quart weighs 2 lb.
** - 1 level teaspoon contains 8 grams of sodium chloride.